

THE DIGITIZATION OF NDT RADIOGRAPHS USING A LASER SCANNER FOR IMPROVED PRODUCTIVITY

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To properly begin a discussion on the improvement of productivity using radiographs, we must define three terms. First, an NDT radiography is defined as the image of an object on an NDT x-ray film. Second, productivity is defined as the output of the system measured as a percent of effort or what comes out of a system as compared to what was put in. Third, a bottleneck or the limiting factor to productivity, is a facility, function or workstation where jobs arrive faster than they leave. Having defined these terms, we know that eliminating bottlenecks in the radiographic process should increase output and improve productivity. The bottlenecks that occur using radiographs are shown in Table 1.

Radiographs necessitate exposure time from several minutes to several hours, depending on the part to be inspected, with a wet processing time of 8-12 minutes. Given the basic nature of the photographic process, both exposure time and processing time are reasonably unalterable. What can be removed are the bottlenecks of long interpretation times, long and costly storage and retrieval, and special studies done with conventional film for increased image visibility and more accurate analysis.

Table 1. Bottlenecks Using Radiographic Film

- o Exposure Time - Minutes to Hours
- o Processing Time - 8 to 12 Minutes
- o Image interpretation time - typically 2 to 3 minutes
- o Storage and retrieval time - 5 minutes to several hours
- o Cost
 - Film - \$3.50 per 14 x 17
 - Exposure - \$7.00 (2 films)

Table 2. NDT Film Characteristics

| | |
|--------------------|--|
| o Optical Density | 0.15 to 7.0 |
| o Average Gradient | 6.0 |
| o Resolution | 20 line prs/mm |
| o Noise [1] | Sigma OD = .012 (@ 1MM ²) = 203:1 signal to noise |

Table 2 shows the functional characteristics of a typical Class I NDT film. With an optical density range of nearly seven decades, average gradients of 5.5-6.0 and resolution as much as 20 lines per millimeter, radiographic film has the properties which keeps it specified as the image capture medium of choice.

Table 3 shows a comparison of real-time versus radiographic film. Real-time significantly improves productivity by eliminating the production time and cost associated with film imaging prior to the image interpretation stage. [2]

Despite lower productivity, radiographic film continues to be specified as the image capture medium of choice because spatial resolution requirements and archival needs exceed real time capability.

Acknowledging that film has inherent capability that makes it the specified image capture medium of choice, yet inherent difficulties in exposure and wet processing time, one must address reducing or eliminating the bottlenecks from image interpretation and storage if we are to improve the productivity of using NDT radiographs. The solution is to digitize radiographic images to improve the reliability and speed of image interpretation following exposure and processing.

Table 3. Real Time vs. Film Radiography

| | <u>Real Time</u> | <u>Film</u> |
|------------------------------|------------------|---------------|
| Speed | Fast | Slower |
| Consumable cost/exposure | - | 3.50/sheet |
| Equipment Cost | ? | - |
| Spatial resolution | 1 line mm | 20 line pr/mm |
| Digital image interpretation | Yes | Yes |
| Ditigal archive | Yes | Yes |
| Film archive | No | Yes |

Prior to 1987, digitization of an NDT radiograph was not feasible because:

- o The performance of available systems was inadequate to reproduce spatial resolution, optical density and the signal to noise ratio that NDT film was capable of, or
- o Scan times were too long

Table 4 shows the results of a study using three independent readers reading for penetrameter sensitivity using a radiographic and video image. The results indicate that the digital reproduction of an NDT radiograph on a video display provides an improvement in penetrameter sensitivity for all NDT films. Class I and Class II films show improvements in sensitivity, but even more significant are those improvements in the Class III film. The results demonstrate that any radiograph now can be scanned without significant information loss, and that with digital contrast enhancement, a significant improvement in image quality, defect visibility, and reliability of interpretation can be obtained.

Table 4. Equivalent Penetrameter Sensitivity, Radiograph vs. Digital Image

| <u>Film Type</u> | <u>Radiograph</u> | <u>Video*</u> | <u>Difference</u> |
|------------------|-------------------|---------------|-------------------|
| Class I | 1.34 | 1.30 | + .04 |
| Class I | 1.52 | 1.37 | + .15 |
| Class II | 1.46 | 1.31 | + .15 |
| Class III | 1.66 | 1.47 | + .19 |

*2X magnification - contrast and density adjusted by readers

Table 5 indicates that a radiograph scanned at 70 micron resolution can be adequately displayed on a thousand line monitor, producing image quality equivalent to the analog film image with no significant image loss.

Table 5. digital Scanner - Spatial Resolution

| <u>Pixel Size Microns</u> | <u>Equivalent Line Pairs/MM</u> |
|-------------------------------|-------------------------------------|
| 70 | 7 |
| 100 | 5 |
| 200 | 2.5 |
| 300 | 1.33 |
| 400 | 1.25 |

Table 6 shows performance capabilities of a first and second generation digitizer. FD 2000 with the dynamic range of 0-3.50 adequately reproduces the dynamic range of an NDT film. Sampling resolution at 100 microns with a bit depth of 12 adequately reproduces the resolving power and the gradient of most NDT images. A signal to noise ratio of 100-1 will not add significant noise to degrade the image. [4] Scan times at 12 seconds obviously are well below those laboratory scanners that while able to reproduce the recording qualities of film had unacceptable scan times of 3, 5, 15 minutes or longer.

NDT Scan more adequately meets the needs of the NDT radiographer for digital information. With dynamic ranges of 0-3.8 or 1-4.8 all currently known government density recording specifications can be met in reproducing an NDT radiograph digitally. At 35 microns, the smallest significant defects can be recorded. At a noise level of 1000-.1 measured at a 3.0 optical density, the digital NDT image will not be degraded by noise added from the electronic system even at a density of 4.0. Further, the scan time of 30 seconds should not significantly impact productivity in a production environment.

NDT radiographs digitized with the FD 2000 or NDT Scan can be digitally reproduced without significant information loss or long scan times. On that basis, digital radiographic data is now available for image processing and quantitative analysis.

Table 6. Radiographic Scanner Performance Capabilities

| | FD 2000 | NDT Scan |
|------------------------------------|--------------------|---|
| Dynamic range (optical density) | .00-3.50 | .00-3.80 1.0-4.80 |
| Sampling resolution | 200 or 100 microns | 70 or 75 microns |
| Bit depth (log) | 12 | 12 |
| Sampling matrix | 2K ² | 5K ² @ 70 microns 10K ² @ 35 microns |
| Noise | 100:1 @ 3.00 OD | 100:1 @ 4.00 OD @ ODR 1.0-4.8 |
| Scan Time | 12 seconds | 30 seconds |

Table 7 lists the applications where digital radiographic imaging can improve interpretation, lower cost and increase productivity.

Storage and retrieval, image transmission (teleradiography), and data matrixing which in the future will make available the matrixing of electronic data from other digital modalities are also possible. In Table 8, the data requirements for storing digital radiographic information is shown. At 70 micron resolution, a 14 x 17 radiograph contains 45 megabytes of information. On a two gigabyte optical disk, approximately 32 14 x 17 radiographs can be stored for an approximate cost per image of \$9.00 per radiograph or approximately \$1.10 per radiograph at 200 micron resolution. Considering the high cost of off-site storage and the limitations of accessing that off-site storage, the actual cost per radiograph for traditional storage and retrieval is considerably higher.

Table 7. Applications for Digital Image Enhancement

- o Reduce image analysis time
- o Improve accuracy of area and density measurement
- o Improve reliability of analysis
- o Reduce multiple film shots
- o Use of lower cost Class II or IV films where specifications allow
- o Reduce need for Neutron Radiography
- o Reduce need for specialty shots, e.g., micro focus blade enlargement

Table 8. Film Digitization Data Requirements

| Pixel Size (Microns) | Storage Requirements M Bytes* | |
|-------------------------|----------------------------------|---------------|
| | 14" x 17" Film | 7" x 17" Film |
| 70 | 44.6 | 22.3 |
| 100 | 21.7 | 10.9 |
| 200 | 5.4 | 2.7 |
| 400 | 1.4 | 0.7 |

*12 bits per pixel, 1.5 bytes per pixel

Now that NDT radiographs can be accurately reproduced without significant information loss, let us consider the future use of tutorial (semi-automated) or automated image analysis algorithms. While the practicality of such systems remains to be proven, several "smart" systems for weld interpretation are under development. These systems will use either radiographer "prompts" to improve the speed and reliability of human interpretation or fully automated pattern recognition to remove the average annual cost of \$30,000 per year for one radiographer. Eliminating 50% of all radiographs from manual analysis amounts to \$15,000 per year saved per radiographer. The result is the removal of the image analysis bottleneck and the improvement of radiographic image analysis productivity and lower image analysis cost.

CONCLUSION

NDT radiographs can now be digitized without significant information loss. Defect recognition and image analysis can be improved, analysis time can be reduced, and film consumption can be lowered. The result is an overall increase in productivity for radiographic inspection.

REFERENCES

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